DUWMULLLO 20 11K78

Luminescence and Gain in Co-Sputtered Al_2O_3 Erbium-Doped Waveguides

Klein L. Johnson, Anand Gopinath, William Berglund and Ben Ellerbusch
University of Minnesota Dept. of Electrical Engineering
4-174 EE/CSCI Blgd. 200 Union ST SE
Minneapolis, MN 55455
Phone: (612) 625-3054

Carol Ford, Randy Ramberg, and Lance Vreze
Honeywell Military Avionics Division
200 Stinson Ave. SE
Minneapolis, MN 55455
Phone: (612) 5203

Abstract: Luminescence and lifetime data is presented for Er-doped Al_2O_3 planar waveguide amplifiers fabricated on Si substrates by co-sputtering.

Luminescence and Gain in Co-Sputtered Al_2O_3 Erbium-Doped Waveguides

Klein L. Johnson, Anand Gopinath, William Berglund and
University of Minnesota Dept. of Electrical Engineering
4-174 EE/CSCI Blgd. 200 Union ST SE
Minneapolis, MN 55455
Phone: (612) 625-3054

Carol Ford, Randy Ramberg, and Lance Vreze
Honeywell Military Avionics Division
200 Stinson Ave. SE
Minneapolis, MN 55455
Phone: (612) 5203

Introduction

Rare earth doping of planar waveguides may potentially yield very compact optical amplifiers, lasers, and amplified spontaneous emission light sources, as well as zero insertion loss waveguide routers, splitters, and multiplexers. Among the most developed to date are Er^{3+} doped devices which emit at around 1530nm and can be pumped efficiently at 980 or 1480 nm. Interest in these devices has inspired a great deal of research into Erbium-doped thin film and bulk materials. Presently, active devices have been fabricated from silica-based [1], crystalline LiNbO3 [2], and sputtered Al_2O_3 dielectric films[3], to name just a few. Typically, incorporation of the Erbium is accomplished through ion implantation, indiffusion, or by sputtering from preconstituted targets. While ion implantation provides good control of the dopant profile, a high temperature (~800C) anneal is required to activate the Erbium ions and remove the damage to the host material caused by the high energy ion bombardment. Diffusion also is a high temperature process, and may require in excess of 100 hours to achieve several microns penetration into the host material. Sputtering from preconstituted targets provides excellent compositional control, yet can be expensive as a new target is required for each experimental run.

We have developed a process with which to deposit truly amorphous Al_2O_3 films suitable for the fabrication of waveguides with very low bulk scatter losses. Al_2O_3 has a structure very similar to Er_2O_3, suggesting that high Er doping levels may be possible in this material without the onset of clustering effects.[3] As an alternative to the above processes, we have developed a process for the fabrication of Er-doped Al_2O_3 waveguides which involves the co-deposition of the Erbium atoms by simultaneous sputtering along with the host material. This method has shown to provide excellent control over compositional parameters, and a high degree of optical activity in the deposited films.

Experimental

In order to investigate the luminescence properties of the doped Al_2O_3 films, we fabricated SiO_2 stripe loaded channel waveguides with the doped Al_2O_3 films comprising the guide region. Samples for analysis were prepared in the form of a typical slab waveguide geometry. Initially, a 3.0 micron SiO_2 buffer layer with a refractive index of 1.49@6328A was sputtered on a 4" silicon substrate. Erbium and Erbium/Ytterbium doped thin films of Al_2O_3 (refr.index=1.8) were then deposited by co-sputtering using annular targets to a thickness of 0.6 microns to form the waveguide core region, followed by a 1.0 micron SiO_2 cap layer. Control of Erbium concentration is achieved by variation of target size and position. Stripe-loaded waveguides were then formed by etching 5.0 micron wide lines in the top SiO_2 by CF_4 RIE through a 75 nm Cr mask. Finite-difference modeling has shown this configuration to be single mode at 1500nm, while marginally supporting a second-order mode at 980nm.

Results

A series of runs were performed utilizing Er alone, along with samples co-doped with Yb to improve pump utilization and emission bandwidth. The doping levels ranged from 0.05 to 0.1 a.t.% for the Er and were held constant at 0.2 a.t.% for the Yb. Luminescence and lifetime data was collected by endfire coupling light from a 100mW 974nm semiconductor laser diode pump into the cleaved end-facets of the waveguides and observing the emitted light by coupling into a 1-meter scanning monochromator equipped with a InGaAs photodetector.

A typical luminescence spectra is shown in Fig.1, corresponding to an Er concentration of 0.1 a.t.% as verified from RBS data. A 500C post deposition bake step has shown to improve the observed radiative lifetimes. Figure 2 shows the lifetime data for the investigated compositions, indicating a 40% increase over the unbaked data. The relatively short 4 mSec lifetimes observed do not quite compare with the 6-10mSec lifetimes previously observed in Al_2O_3 [3] and the 10-12mSec lifetimes typical of silica-based hosts.[4] However, initial indications suggest that this can be improved through refinement of the deposition and bakeout procedures.

We have also observed amplifying behavior in these waveguides by coupling a ~1500nm signal from an external cavity tunable diode laser into one facet while backward pumping the sample from the other end with the pump laser. We have measured in excess of 1.0dB/cm internal gain at λ=1530nm for 20mW launched pump power. Further data on the amplifying behavior, lifetime studies, and absorption/emission cross sections will be presented.

Conclusions

Simultaneous co-sputtering has been shown to be a possible means for the economical fabrication of Erbium-doped waveguide devices based on Al2O3, and can easily be extended to other host materials. Lifetime studies have shown that further improvements can be made, possibly making this technology comparable to silica based materials.

References

[1] J. Shmulovich, et al., *Optical Fiber Communication*, 1996 OSA Tech. Digest Series, pp.250-51.

[2] W. Sohler, *Integrated Photonics Research*, Vol. 7, 1995 OSA Tech. Digest Series, pp.212-14.

[3] G. N. van den Hoven, et al., J. Appl. Phys., Vol. 79, No. 3, pp.1258-66, 1996.

[4] E. Desurvire, "Erbium-Doped Fiber Amplifiers: Principles and applications", John Wiley & Sons, Inc., New York, 1994.

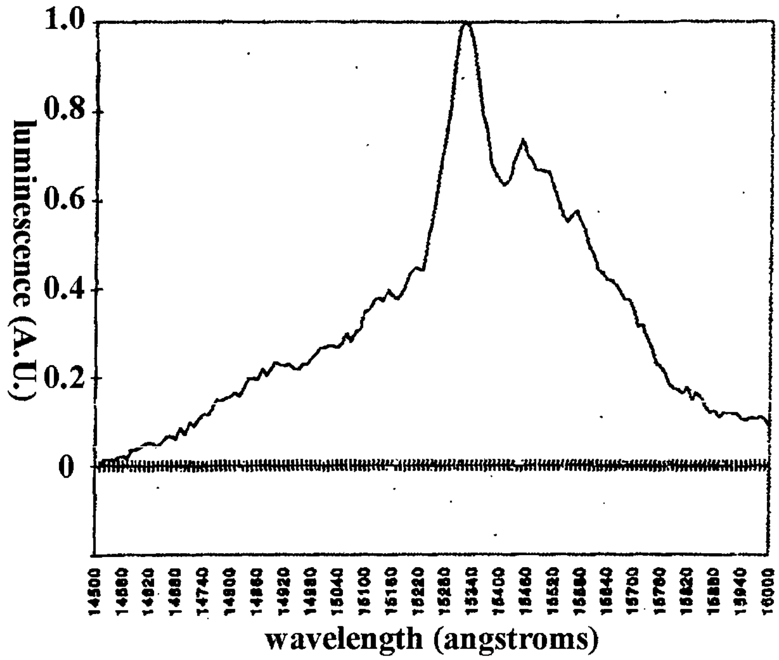

Figure 1. Luminescence of Al_2O_3 waveguide with 0.1 a.t.% Er doping pumped at 974 nm.

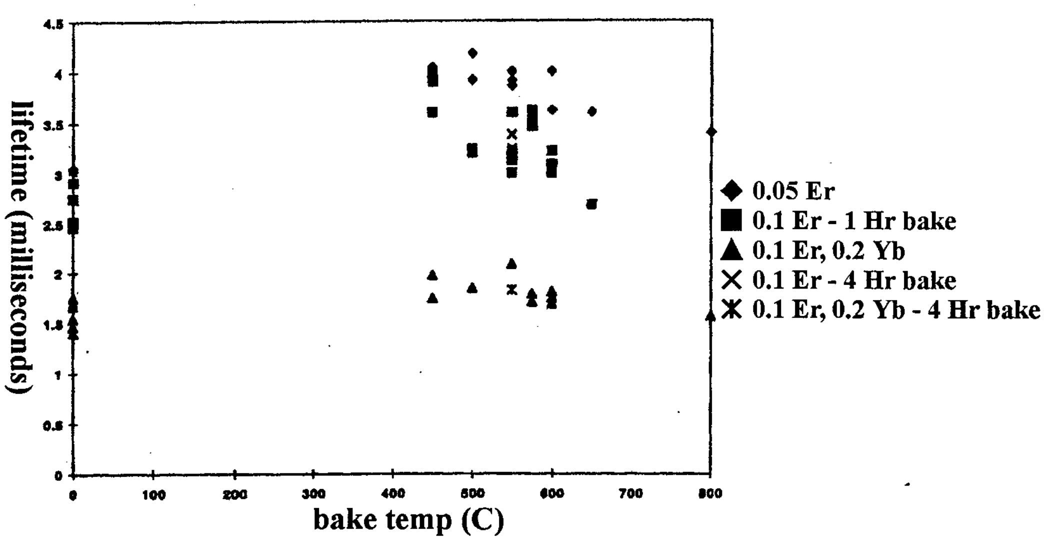

Figure 2 under various baking Observed radiative lifetimes of Er and Er/Yb doped Al_2O_3 waveguides conditions.